The Influence of Waste Tire Powder on the Properties of Waste Tire Powder/Polypropylene Plastic Composite

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Abstract. The use of waste tire powder (WTP) as a polypropylene (PP) property enhancer in plastic composite has been prepared. Scanning electron microscopy (SEM), Fourier Transform Infrared Spectroscopy (FTIR) and mechanical testing have been used to measure the properties of PP/WTP. Sample morphology shows that there are no impurities in post-fracture images on both PP and PP/WTP. Apart from that, it can be seen that the surface of PP / WTP is slightly smooth. PP and PP/WTP are nearly similar in the FTIR spectrum. During tensile and flexural tests, the PP/WTP value drops as the WTP amount increases. For elongation break and impact testing, PP/WTP at 40% WTP exhibits highest strength value compare to other samples. In all cases, WTP with smallest range of size (250–500 μm) shows better mechanical performance compare to other sizes. PP/WTP plastic composite has a highly great potential to be used in most plastic manufacturing industry and sustain the green environment by taking the advantage of waste tire powder.

1. Introduction

Tire, a complex component with many distinct materials which is difficult to identify. It requires a lot of energy with multi-processes during recycling. Numbered of solutions and processes are needed to establish for preventing the abundance of waste tire. In developing countries, phenomenon of waste tire abundancy is overlooked due to poor environmental policy, soft regulatory compliance and lack of adequate technology work together to intensify the situation [1].

Around 1.4 billion of new tires are sold worldwide per year, which potentially turn into waste in a short period of time [2]. Approximately, 4 billion of waste tires are being uselessly stockpiled in landfills, which leads to health problems that are associated with the contamination. This problem

presents major challenges in science and engineering, to provide effective solution through new technology powered by green approached [3-5].

Compounding of waste material with thermoplastic is a new approach, where waste material works as property enhancer and directly reduce the abundancy of it. In this work, WTP has been used as a property enhancer for PP in the plastic composite making. The effect of WTP in PP has been investigated by using SEM, FTIR and mechanical testing.

2. Materials and method

2.1. Materials

Waste tire powder (WTP) was collected from local tyre recycling centre with particle size of approximately more than 2 mm. The polypropylene (PP) was supplied by local plastic industry with a melt flow index (MFI) of 14 g/min and density of 900 g/cm^3.

2.2. Preparation of waste tire powder (WTP)

WTP was first clean with washed water to remove the dirt and unwanted substance and oven dried at 60°C for 12 h. WTP was further grinded with a grinder by using a sieving shaker (RETSCH, AS 200 Basic). The particle size was separated into three size ranging from 250–500 µm, 500–710 µm, and 710 µm –1 mm and used as filler.

2.3. Composite preparation

PP were mechanically mixed with different size and composition of WTP to obtain the specimens. PP/WTP were subjected into injection moulding. The blends were preheated for 6 min and compression-moulded at 200 ° C for 4 min. Afterwards, the blends were left to be cooled under pressure at an ambient temperature for 2 minutes. All the specimen (dumbbell and round shape) was kept in the plastic bag for further characterization.

2.4. Scanning Electron Microscopy (SEM) Analysis

Surface morphologies of PP and PP/WTP were analysed with scanning electron microscopy (ZEISS, EVO 50, Germany). Before observation under the SEM instrument, samples were coated with platinum using a sputter-coater.

2.5. Fourier Transform Electron Microscopy (FTIR) Analysis

The interaction between PP, WTP and PP/WTP were investigated by Fourier Transform Infrared Spectroscopy (FTIR). The samples were mixed with KBr and a range of 4000-400 cm-1 FTIR spectrum was observed.

2.6. Mechanical Testing

The tensile test was conducted in compliance with ASTM D638. Using a crosshead speed of 20 mm / min, testing was carried out at room temperature. The mean value of each sample of five specimens was measured. The tensile strength and elongation at break values were calculated using software.

Samples dimensions of 75 × 12 × 2.5 mm3 were cut into compression molded plates in accordance with ASTM D790. Flexural tests (60 mm span) were carried out on an Instron model 5565 with a load cell of 500 N at room temperature (23°C) using a crosshead speed of 5 mm/min. In order to get an average for flexural modulus, each concentration was checked with a minimum of five specimens.

Rectangular specimens (110 × 12 × 2.5 mm3) were cut from the moulded plates in compliance with ASTM D6110 for the notched Charpy impact examination the samples were then notched with an ASN120 mm automatic Dynisco notcher model. Ten samples were tested for each concentration on a Tinius Olsen Impact 104 model to extract an average impact intensity for each composition. In all situations, standard deviations were less than 10%.

3. Results and Discussion

3.1. Scanning Electron Microscopy (SEM) Morphology

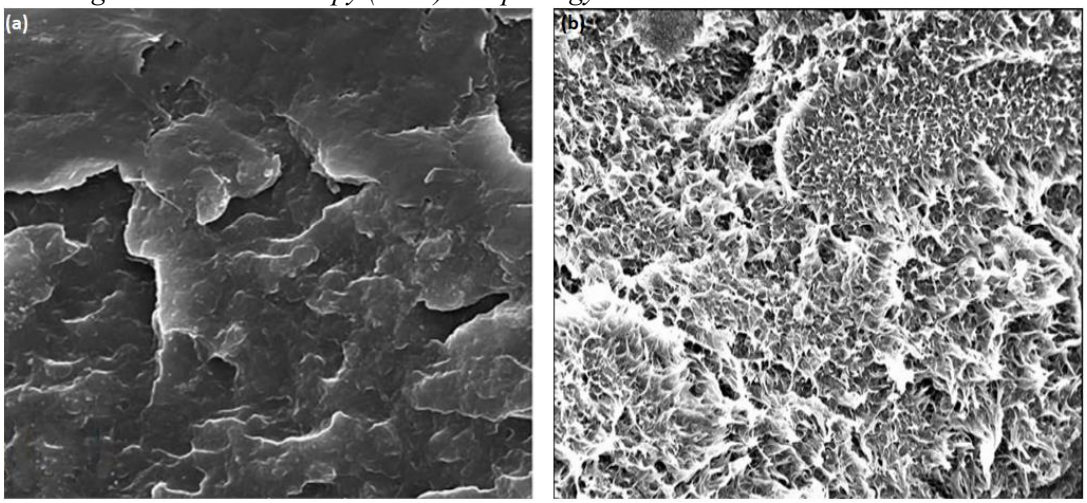

Figure 1. (a) SEM micrograph for Polypropylene (PP), (b) SEM micrograph for waste tire powder fill polypropylene (PP/WTP)

Figure 1 shows the SEM images of fractures surfaces polypropylene and waste tire powder fill polypropylene. Virgin PP (Figure 1a) has fragmented and nearly smooth surface. Meanwhile, Figure 1b shows the SEM micrograph of the PP/WTP, where the surface structure is moderately smooth and displays no signs of plastic deformation or drawing. It was visible that the WTP and PP compressive bonding had no gap, hole or impurities, witnessing matrix filler sound bonding ability [6].

3.2. Fourier Transform Electron Microscopy (FTIR) Analysis

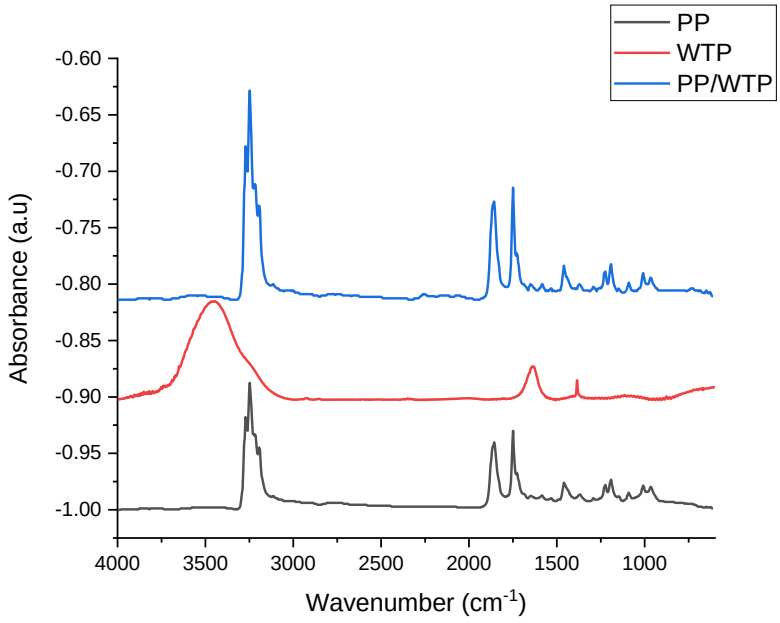

Figure 2. FTIR spectra of PP, WTP and PP/WTP

The FTIR spectra of PP, WTP and PP/WTP in the range of 4000-400 cm^{-1} is presented in Figure 2. PP displays its peak characteristics at 1853 cm^{-1} attributed to the asymmetric stretching vibration of -C-H-

in CH_3 and 1744 cm^{-1} assigned to the bending symmetry of CH_3 [7-9]. Absorption peaks displayed at 966 and 1187 cm^{-1} are assigned to -CH_3 rocking vibration [9].

Meanwhile, the spectra in WTP visualise three visible peaks. The peak at 3500-3300 cm^{-1} correspond to O-H [10, 11] and N-H group [10, 12]. The C-S bond was attributed to another peak traced at 1538 cm^{-1}, which represents untreated WTP [13]. An important 1371 cm^{-1} WTP spectrum peak that corresponds to aliphatic C-H bend vibration of the CH_3 group [14].

It can be seen that the PP and PP / WTP spectra were mostly identical, without any noticeable difference in peak position. Zainal and Ismail [15] reported the abundance of the C-H bond form in WTP and PP. The characteristic peaks at 3349 cm^{-1} were due to the -OH group, and the 1750-1720 cm^{-1} region may be due to nitrile type of substituent in the aliphatic chain [16], or a carbonyl compound (possibly ester or ketone) of WTP [17, 18] present in the PP/WTP.

3.3. Mechanical Testing

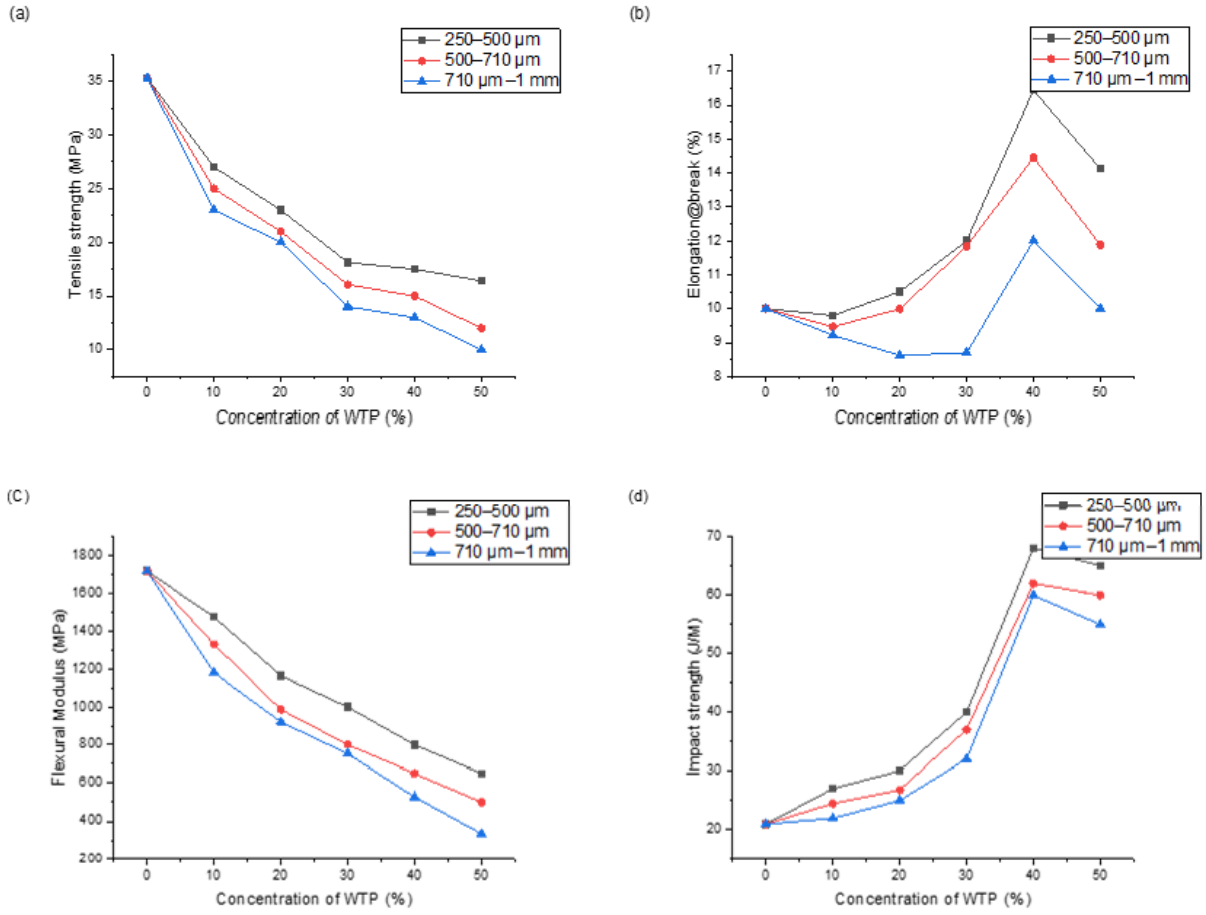

Figure 3. (a) Tensile strength with various size of PP/WTP, (b) Elongation at break with various size of PP/WTP, (c) Flexural Modulus with various size of PP/WTP, (d) Impact strength with various size of PP/WTP

Figure 3 shows the effect of tensile strength, elongation at break (EB), flexural modulus and impact strength on different size of PP/WTP with different ratio. As can be seen on Figure 3a, the tensile strength decreased with increasing of WTP concentration. At higher WTP concentration, declination in tensile strength was seen attributed to agglomeration of the WTP. On the contrary, the lower WTP content visualizes the elastomer process as scattered particles and leads to a higher tensile strength value. A similar study is reported by Başboğa, Atar [19], where they found that agglomeration of WTP was

occurred when WTP content is increasing in PP matrix. Furthermore, blending PP with fine WTP possess slightly higher tensile strength compared to coarse WTP blends, showing that better adhesion between WTP and PP matrix as can be seen in SEM morphological study (Figure 1).

Figure 3b demonstrates the impact of blending concentration and WTP sizes on the EB of the PP/WTP blends. It can be seen that, EB increased linearly with the addition of WTP concentration until 40% and drop at 50% WTP. This might be due to excessive of rubber contains in composite which decrease in the performance of the elongation. It can be seen that, WTP with smaller size possess higher EB value compared to coarse WTP. The findings are in agreement with Zainal and Ismail [15], where WTP with coarse size brought poor adhesion quality between WTP and matrix that leads to the rapid propagation of cracks.

Flexural modulus of PP/WTP is presented in Figure 3c. It is shown that the value of flexural modulus dropped as the concentration of WTP increased. The same pattern of flexural value has been observed by Shivamurthy, Doreswamy [20] where higher concentration of WTP leads to agglomeration. The decrease of flexural value is might be due to the increasing of elasticity characteristics which will make the specimen easier to reach the maximum strain. Moreover, smaller size of WTP shows better flexural properties.

The effects of WTP on impact strength was displayed in Figure 3d, where it was verified that the increment of WTP concentration obtain better impact strength properties. However, the increasing trend of impact strength starts to drop during the composition of 50% WTP. WTP at 0% had the lowest impact value due to the high crystallinity characteristics [21]. The impact resistance is directly related to the polymer matrix crystallinity. Thus, the greater the degree of crystallinity, the greater the thermoplastic matrix rigidity, and the lower the energy absorption under impact. WTP 40% shows the optimum impact value due to the addition of tire rubber powder which decreases the stiffness of the composites and increased their impact absorption capacity [22]. The similar findings reported by Liu and Zhang [23], where the value of impact strength drop due to weak load-bearing capacity of rubber powder.

4. Conclusion

PP/WTP was successfully prepared and characterized through SEM, FTIR and mechanical testing. It can be seen that the surface morphology of PP/WTP was moderate smooth and no visible impurities was observed, reveals that the better adhesion between PP and WTP. FTIR spectra determine that the trend of PP and PP/WTP was fairly significant in terms of peak and functional group. Meanwhile, the findings on mechanical testing affirm that PP and WTP blend reveals the effectiveness of PP/WTP and achieve optimum value in 40% WTP on elongation at break and impact strength testing.

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